Norfolk CSO Sediment Cleanup Study

Elliott Bay/Duwamish Restoration Program

Prepared for the
Elliott Bay/Duwamish Restoration Program Panel
by the
King County Water Pollution Control Division

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The Panel, its technical working groups and its committees hold regularly scheduled meetings that are open to the public. Meetings are generally held at the National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center auditorium, 2725 Montlake Boulevard East, Seattle. Because meetings are sometimes rescheduled and locations changed, the Panel recommends that you contact Robert C. Clark Jr., Administrative Director, at (206) 526-4338 to confirm the meeting schedule. The Panel also schedules periodic special meetings, such as public information meetings and workshops.

Regularly scheduled meeting dates
Panel: First Thursday of every month, 9:30 a.m.-12:30 p.m.
Sediment Remediation Technical Working Group: Second and last Thursday of every month, 1-4 p.m.
Habitat Development Technical Working Group: Second and last Thursday of every month, 9 a.m.-noon
Public Participation Committee: Second Monday of every month, 1:30-4 p.m.

Environmental Review of Specific Projects
Formal hearings and comment periods on appropriate environmental documents for each proposed sediment remediation and habitat development project will be observed. Please contact the Administrative Director for more information.

This information is available in accessible formats on request at (206) 684-2046 (voice) or (206) 689-3413 (TTY/TDD users only).

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LIST OF ACRONYMS

ACOE	U.S. Army Corps of Engineers
AET	Apparent Effects Threshold
ASTM	American Society of Testing Materials
AVS	Acid Volatile Sulfides
BNA	Base/Neutral/Acid Extractable organic compounds
CAD	Confined Aquatic Disposal
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
City	City of Seattle
COCs	Chemicals of Concern
CSL	Cleanup Screening Levels
CSO	Combined Sewer Overflow
CVAA	Cold Vapor Atomic Analysis
CWA	Clean Water Act
DNR	Washington State Department of Natural Resources
DW	Dry Weight
DWU	City of Seattle Drainage and Wastewater Utility
EA	Environmental Assessment
EBDRP	Elliott Bay/Duwamish Restoration Program
Ecology	Washington State Department of Ecology
EDMI	Electronic Distance Measuring System
EPA	U.S. Environmental Protection Agency
FONSI	Finding of No Significant Impact
HCID	Hydrocarbon Identification method
HH	Halogenated Hydrocarbons
HSWA	Hazardous and Solid Waste Act
HPAH	High Molecular Weight Polycyclic Aromatic Hydrocarbons
I/I	Infiltration/Inflow
ICP	Inductively Coupled Plasma
KC	King County
KCDMS	King County Department of Metropolitan Services
KCWPCD	King County Water Pollution Control Department
KCIA	King County International Airport
LAET	Lowest Apparent Effects Threshold
2LAET	Second Lowest Apparent Effects of Threshold
LPAH	Low Molecular Weight Polycyclic Aromatic Hydrocarbons
MCUL	Minimum Cleanup Levels
MDL	Method Detection Limit
MG	Million Gallons
MGD	Million Gallons Per Day
MGY	Million Gallons Per Year

MLLW	Mean Lower Low Water
MTCA	Model Toxics Control Act
NCD	Nearshore Confined Disposal
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEP	National Estuary Program
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NRDA	Natural Resource Damage Assessment
NTR	National Toxics Rule
OC	Organic Carbon
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PSD	Particle Size Distribution
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
PSWQA	Puget Sound Water Quality Authority
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RDL	Reporting Detection Limit
QA/QC	Quality Assurance/Quality Control
SAP	Sampling and Analysis Plan
SEPA	State Environmental Policy Act
SIM	Single Ion Monitoring
SMC	Seattle Municipal Code
SMS	Sediment Management Standards
SQS	Sediment Quality Standards
SPPP	Stormwater Pollution Prevention Plan
SRTWG	Sediment Remediation Technical Working Group
TCLP	Toxicity Characteristics Leaching Procedure
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
USC	United States Code
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation
WTPH	Washington Total Petroleum Hydrocarbons method

EXECUTIVE SUMMARY

The Elliot Bay/Duwamish Restoration Program (EBDRP) was established to implement the requirements of a 1991 Consent Decree defining the terms of a natural resources damage assessment. The goals of the EBDRP include remediation of contaminated sediment associated with Metro (now King County Water Pollution Control Department, or KCWPCD) and City of Seattle combined sewer overflows (CSOs) and storm drains.

This sediment cleanup study report addresses contaminated sediments associated with the KCWPCD Norfolk CSO outfall, which discharges to the Duwamish River in the City of Tukwila. The report combines results of a site assessment and alternatives evaluation. Site assessment activities included identification of contaminants of concern, delineation of the extent and magnitude of sediment contamination around the Norfolk CSO outfall, as well as evaluations of planned CSO-reduction measures and watershed source controls. As part of this effort, KCWPCD performed three rounds of sediment sampling and analysis between August 1994 and December 1995. Results of the site assessment were then used in the alternatives evaluation, which consists of the identification, evaluation, and ultimate selection of a preferred sediment cleanup alternative. Cleanup implementation is tentatively scheduled for December 1997.

Major conclusions of the site assessment component of this cleanup study report are:

- Discharge from the Norfolk CSO outfall includes combined sewer overflows during severe storm events and storm water from five drainage lines connected to the outfall line after the Norfolk overflow regulator. The service areas for these lines include the southern end of King County International Airport, roof drains at the Boeing Preflight Facilities, and street drains and parking lots along E. Marginal Way and S. Norfolk Street between E. Marginal Way and the Duwamish River.

- CSO-reduction efforts are predicted to reduce the annual Norfolk CSO discharges to the Duwamish River from 70 MGY down to 7 to 9 MGY, and reduce annual overflow events from 19 down to 4. These improvements should be fully operational by the beginning of 1997.

- KCWPCD recontamination modeling results and simple spreadsheet calculations indicate that CSO reductions will be sufficient to reduce potential recontamination of sediment to below state sediment quality standards (SQS) for all modeled chemicals. Therefore, the Norfolk CSO is considered to be adequately controlled for cleanup of historical contamination to proceed.

- The model does not account for polychlorinated biphenyl (PCB) hot spots located at Stations NFK305 and NFK315. The source(s) of the PCBs at these locations are not defined. Sediment core data collected near Station NFK315 indicates historical sources rather than ongoing sources, although further evaluation of storm water discharges from both the Norfolk outfall after the regulator and the Boeing storm drain outfalls would be needed to confirm this.

- Additional source control efforts currently being implemented in the Norfolk basin by City Drainage and Wastewater Utility staff include storm drain sediment removal, business inspections, and public education.

- The major chemicals of concern associated with historical discharges from the Norfolk CSO outfall are mercury, 1,4-dichlorobenzene, bis (2-ethylhexyl) phthalate, and PCBs. These chemicals were used to define the areal extent of sediment contamination due to Norfolk CSO discharges. Bioassay data collected during Phase 1 were not used to define areal extent of contamination due to quality control issues.

- Based on kriging contour methods, the combined areal extent of sediment contamination exceeding SQS is estimated at 20,000 square feet for the Norfolk outfall. Depth of sediment contamination was estimated at 2-feet based on sediment coring data. These estimates are exclusive of the downstream PCB hotspot at Station NFK305, which is unrelated to the Norfolk outfall.

- Following completion of the site assessment, several members of the EBDRP Panel became involved in interagency discussions regarding the potential for human health risks due to bioaccumulation of PCBs, as well as potential adverse effects on juvenile salmon migrating through the Duwamish River estuary, even at PCB levels below the SQS. In order to address these concerns, the Panel decided, as part of the planned cleanup at Norfolk, to remediate any additional, accessable sediments below the SQS that contain detected levels of PCBs. Based on this decision, the sediment cleanup area was extended to 32,300 square feet, which represents about 2,400 cubic yards of contaminated sediments in place. It is believed that the benefits of achieving protection of human health and migrating juvenile salmon outweighs the small additional cost of remediating these sediments. The long-term site-specific cleanup standard will still be set at the SQS level for all chemicals at the site, which is consistent with the goals of the sediment source control program.

Major conclusions of the alternatives evaluation component of this cleanup study report include:

- Based on a detailed evaluation of several sediment remedial alternatives, Alternative 3 (mechanical dredging with treatment at Holnam Inc. cement facility) was selected as the preferred alternative, and Alternative 2 (mechanical dredging with upland disposal) was selected as a backup alternative (in case the Holnam Inc. facility cannot accept all dredged sediments).

- Primary justification for the selection of Alternative 3 as the preferred alternative includes: (1) the total cost associated with mechanical dredging ($891,500) is approximately $137,000 less than hydraulic dredging alternatives; (2) mechanical dredging will be easier to implement; (3) treatment at Holnam Inc. will destroy most organic contaminants during the thermal treatment process and residual contamination will be incorporated in cement; therefore the risk of contaminant exposure will be eliminated; (4) the preferred alternative will comply with cleanup standards and applicable laws; and (5) the preferred alternative will remove all contaminated sediment from the site and treat it, therefore community and agency acceptance is expected to be greater.

- Although the volume of contaminated sediments is estimated at 2,400 cubic yards, the actual sediment volume that will be dredged and removed from the Norfolk site is estimated at 7,200 cubic yards. This is based on the required dredge cut depth of 2 feet to reach the bottom of contamination, plus one-foot of overdepth to ensure that all material is removed. Dredged material will be treated offsite.
- PCB hot spot removal at Station NFK315 will occur prior to removing all other contaminated sediments. Sediments exceeding 50 mg/kg PCBs (conservatively estimated at 300 cubic yards) will be disposed at the hazardous waste landfill at Arlington, Oregon.
- Based on Panel input, backfilling the excavated area following dredging operations with clean fill material is proposed. Backfilling will return the sediment elevation to pre-dredge elevations and increase habitat value.
- One-time sediment monitoring will be conducted following sediment cleanup to confirm that sediments are not being recontaminated from current CSO discharges.

1.0 INTRODUCTION

This Sediment Cleanup Study Report characterizes the spatial extent and magnitude of chemical contaminants detected in sediments collected near the Norfolk combined sewer overflow (CSO) outfall, located in the Duwamish River. In addition, this report identifies sediment cleanup areas, evaluates sediment cleanup alternatives, and selects a preferred alternative. The content of this report is consistent with Cleanup Study Report requirements specified in the Washington State Sediment Management Standards (SMS), Chapter 173-204 WAC.

1.1 PROJECT OVERVIEW

In order to implement the requirements of a 1991 Consent Decree defining the terms of a natural resources damage agreement, the Elliott Bay/Duwamish Restoration Program (EBDRP) was established. Program oversight is provided by the EBDRP Panel, which is composed of federal, state, and tribal natural resource trustees, the Municipality of Metropolitan Seattle (which subsequently became part of King County government and is now the King County Water Pollution Control Department, or KCWPCD); and the City of Seattle (City). The goals of the EBDRP include remediation of contaminated sediments associated with KCWPCD and City CSOs and storm drains, and restoration of habitat in Elliott Bay and the Duwamish River.

In 1992, a Sediment Remediation Technical Working Group (SRTWG) was established by the EBDRP Panel to address contaminated sediment issues. The SRTWG identified 24 potential sediment remediation sites associated with KCWPCD and City CSO and storm drains. These sites were evaluated against several criteria which included extent of contamination, degree of source control near sites, and public input, as reported in the *Final Concept Document* (EBDRP, 1994a). Ultimately, the SRTWG selected three sites (Duwamish Pump Station CSO/Diagonal Way CSO/Storm Drain; Norfolk CSO; and Seattle Waterfront) for further investigation. This report addresses only the KCWPCD Norfolk CSO site.

In 1994, the *Norfolk Cleanup Study Plan* was prepared by KCWPCD on behalf of the EBDRP Panel. The documents that comprise this Plan are the Workplan (EBDRP, 1994b), the Sampling and Analysis Plan and Addenda (EBDRP, 1994c, 1995a, b), the Health and Safety Plan (EBDRP, 1994d), and the Public Participation Plan (EBDRP, 1994e). These plans provide the framework for the Norfolk sediment cleanup study. Cleanup implementation will follow the study.

The 1994 Workplan identified five chemicals of potential concern based on preliminary sediment samples collected near the outfall. One sediment sample was collected in 1990 and two sediment samples were collected in 1992. The five chemicals exceeding SMS sediment quality criteria were mercury, 1,4-dichlorobenzene, bis(2-ethylhexyl)phthalate, polychlorinated biphenyls (PCBs), and benzoic acid (refer to **Appendix A,** Pre-Phase 1 Data).

KCWPCD implemented field collection activities described in the Sampling and Analysis Plan/Addenda between August 1994 and December 1995. The primary goal was to determine the extent of sediment contamination around the Norfolk CSO outfall based on comparison to

SMS criteria. The site assessment results identify the boundaries of the sediment cleanup area, and assist in the selection and design of sediment cleanup alternatives.

1.2 REPORT ORGANIZATION

This Sediment Cleanup Study Report combines two main components: site assessment and alternatives evaluation. Site assessment activities included review and interpretation of historical and current data, description of the site, identification of contaminants of concern, and evaluation of source control activities. Alternatives evaluation activities included identification and evaluation of sediment cleanup alternatives. The Sediment Cleanup Study Report is organized into ten (10) chapters listed below:

Site Assessment

- **Chapter 1** provides a project overview and report organization.
- **Chapter 2** describes the environmental setting and natural resources of the project area.
- **Chapter 3** presents a source control evaluation, including identification of contaminant sources, planned CSO reductions, and potential for sediment recontamination based on modeling results.
- **Chapter 4** describes the data collection efforts and chemical results associated with the cleanup study, including sampling and testing methods, QA/QC results, and sediment chemistry results.
- **Chapter 5** presents the data interpretation, including comparison to SMS criteria, evaluation of concentration gradients, comparison to upgradient concentrations, identification of chemicals of concern, and potential contaminant migration and fate.

Alternatives Evaluation

- **Chapter 6** presents a compilation of applicable laws and regulations which govern cleanup at the Norfolk CSO site, and cleanup standards which will be applied to site sediments.
- **Chapter 7** identifies and selects technologies and process options that potentially can be used for sediment remediation.
- **Chapter 8** assembles, screens, and develops alternatives that will undergo detailed evaluation.
- **Chapter 9** presents a detailed evaluation of the alternatives and provides justification for the preferred alternative.
- **Chapter 10** provides cost information on backfilling the site following proposed cleanup actions.

2.0 SITE DESCRIPTION

2.1 PROJECT LOCATION

The Norfolk CSO outfall is located at approximately river km 10 in the Duwamish River. The outfall is located south of Seattle, in the City of Tukwila, Washington (**Figure 2-1**). The 84-inch diameter outfall originates at KCWPCD's Norfolk Street Regulator Station near South 102nd Street, which receives overflows from the Norfolk drainage basin. The study area is situated between the South 102nd Street bridge located upstream, and the Boeing concrete bridge located downstream (**Figure 2-2**). The upper navigational turning basin (Turning Basin #3) is located approximately 0.3 km downstream of the outfall.

2.2 LAND USE AND PROPERTY DESCRIPTIONS

Land use in the vicinity of the site is primarily industrial and commercial, with residential areas located within 1 km (**Figure 2-2**). The site parallels the southern boundary of the Boeing Development Center and Boeing Field. Boeing has proposed the installation of recreational trails near the river. Future shoreline enhancements and trail improvements are planned as part of the Boeing Redevelopment Plan and the programmatic EIS for corridor redevelopment. Downstream of the Norfolk site, intensive port and industrial development has occurred along the banks of the Duwamish Waterway.

The study area is completely within the Tukwila city limits, while the primary drainage basins for both the CSO and storm water into the outfall are primarily within Seattle city limits. The project site is located primarily on state-owned aquatic lands managed by the Washington State Department of Natural Resources (Fran Sweeny, Personal Communication), with the exception of some tideland property owned by Boeing (**Figure 2-3**).

2.3 SHORELINE FEATURES AND BATHYMETRY

The Duwamish River in the vicinity of the site is not maintained for vessel traffic, and some natural shoreline occurs in the area along with relatively natural riparian habitat. The shoreline is distinctly separated by a steep erosional-cut bank joining a sloping intertidal mud shoreline. Pilings (primarily wingwalls), tree stumps, and rock piles are found in the intertidal and subtidal zones at the site. An intertidal mudflat is located immediately downstream of the outfall, and extends as far as the downstream bridge. Upstream there is an old wooden barge and small concrete pad that may once have served as a loading dock; these structures extend from the bank into the river about 30 to 40 feet.

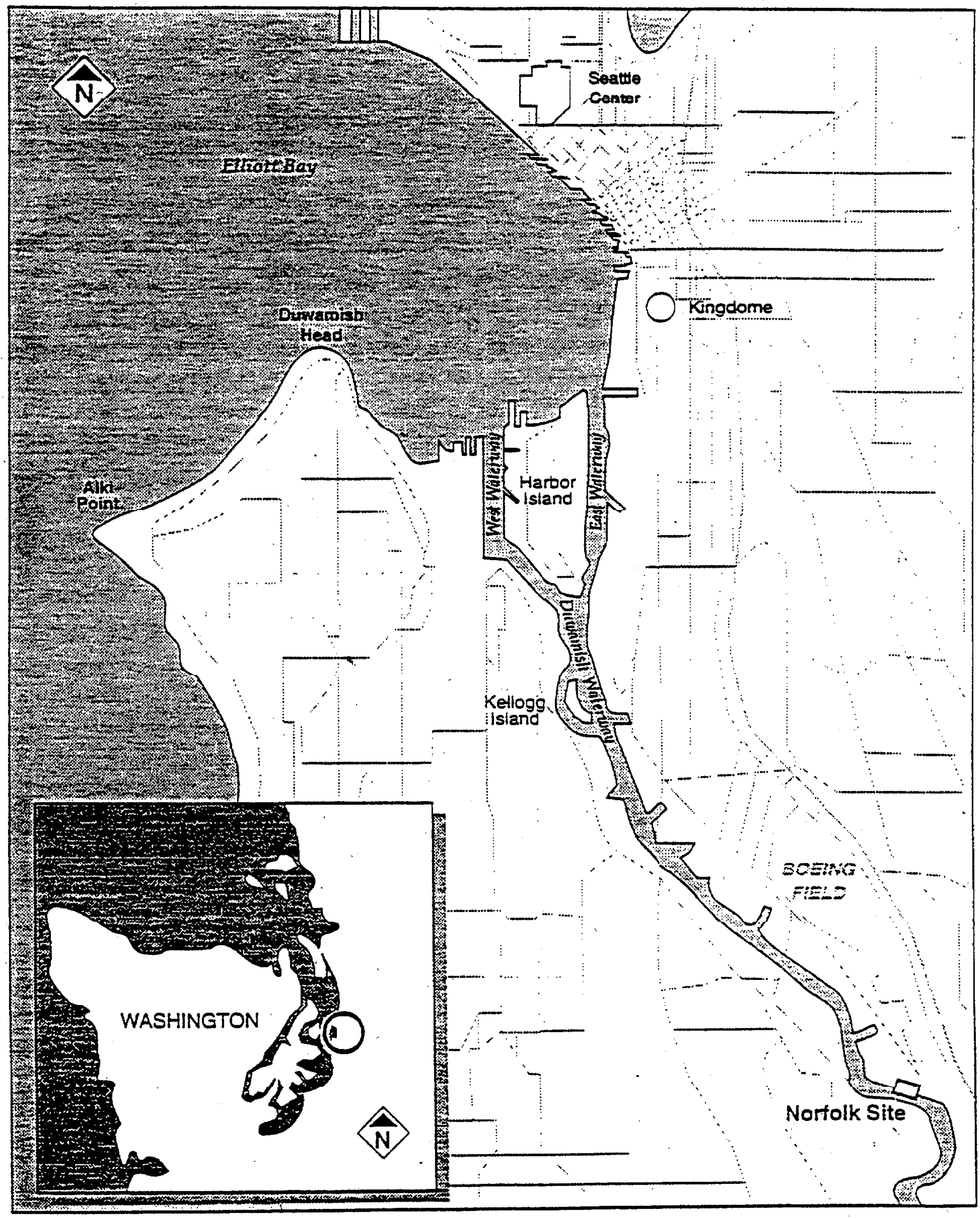


Figure 2-1

Norfolk CSO Sediment Cleanup Study
VICINITY MAP

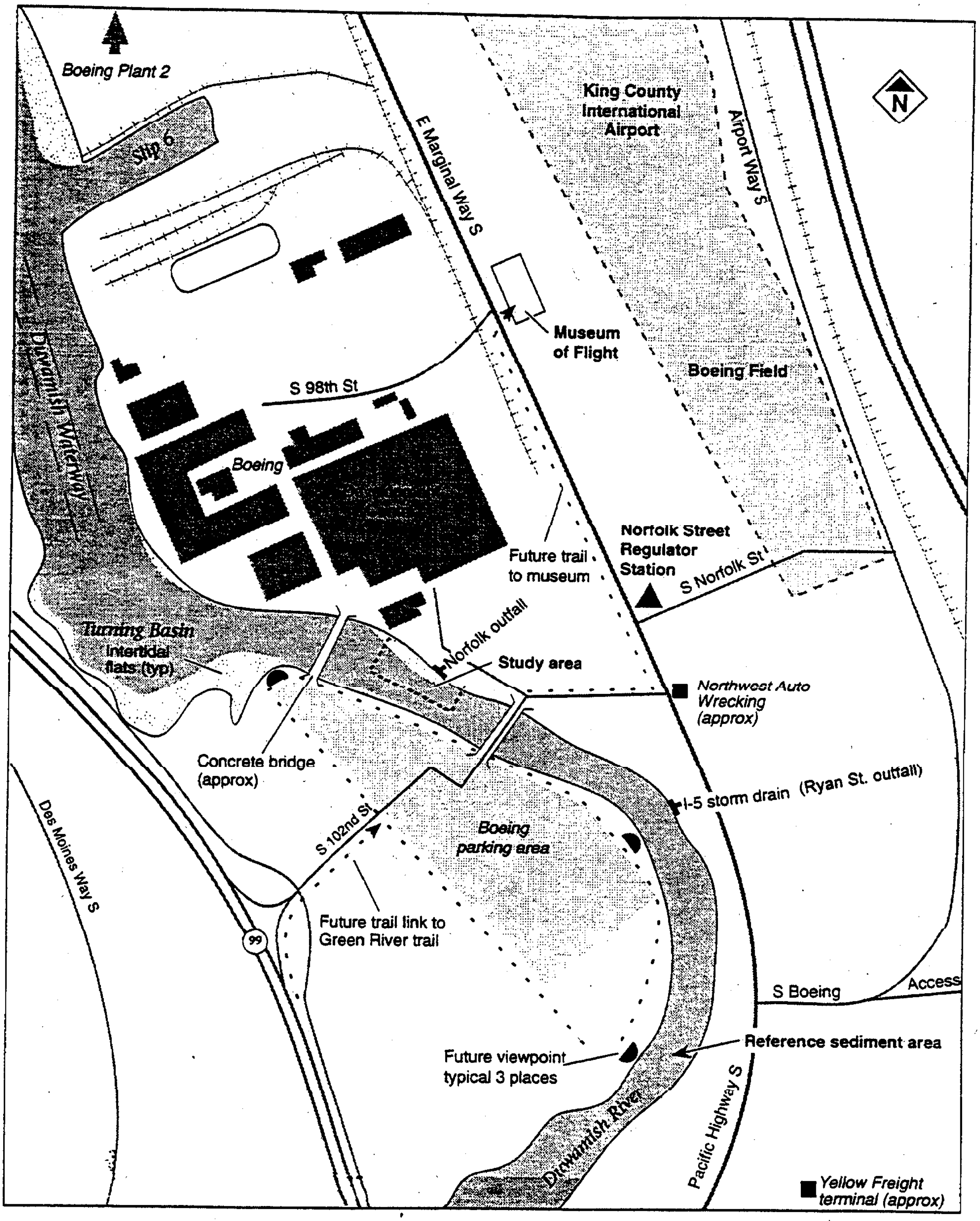
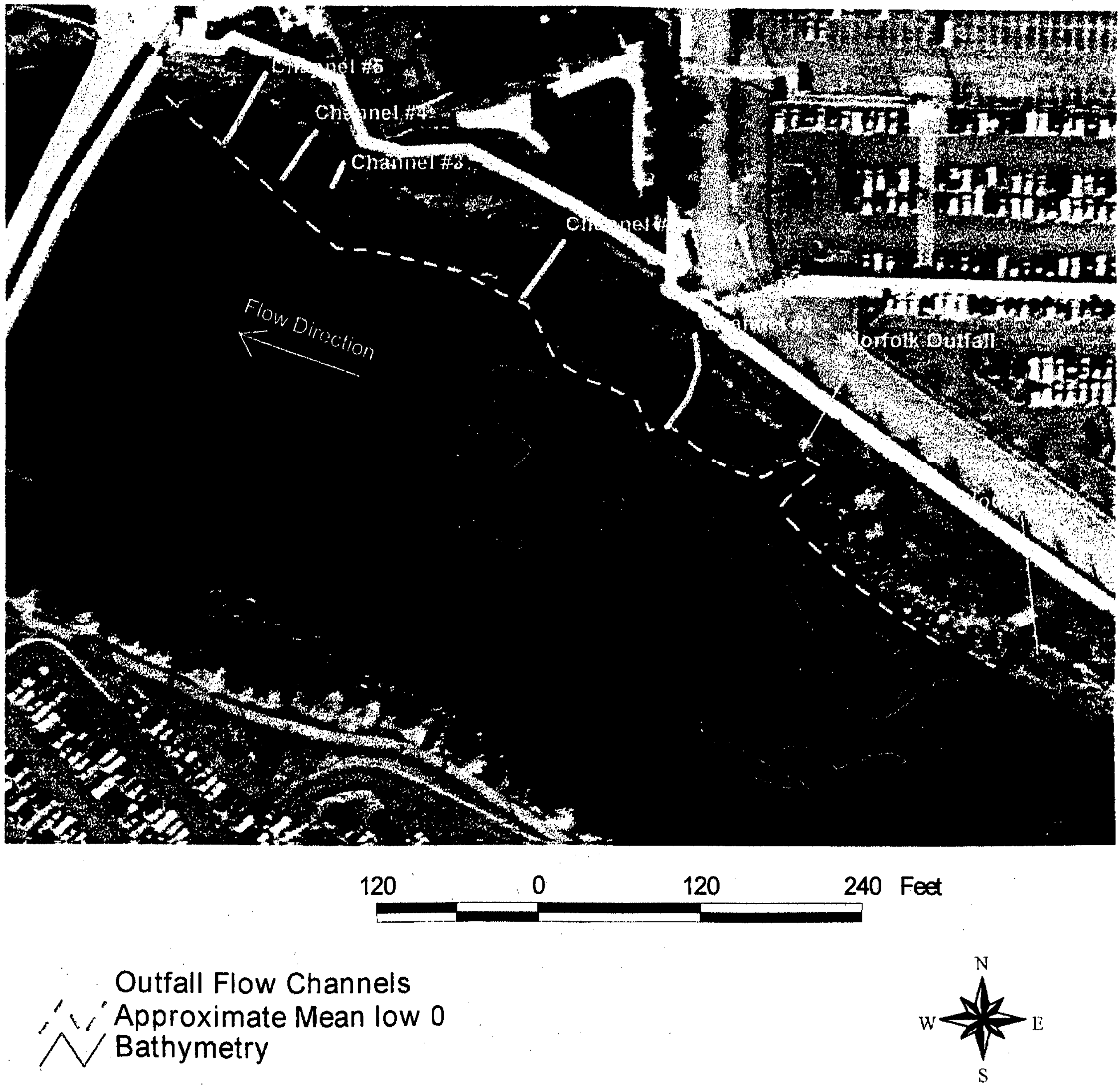


Figure 2-2

Norfolk CSO Sediment Cleanup Study
SITE MAP

Source: USGS, 1973; USGS, 1983; Tanner, 1991; Boeing, 1994.



EcoChem Team	Norfolk Sediment Cleanup Study **Shoreline Features and Bathymetry**	Figure 2-3

A bathymetry survey was conducted at the Norfolk site in 1992, which identified depths between 0 and -6 feet MLLW for the river, and up to +2 feet MLLW for a portion of the intertidal zone. Bathymetry showed that a shallower intertidal area extends 50 to 100 feet offshore, and the river bottom then slopes more steeply to a depth of 6 feet, where the bottom becomes flat in the middle of the river. However, the 1992 bathymetry survey did not identify the location of shoreline features, such as the Norfolk CSO outfall channel and Boeing storm drains. Therefore, as part of the Norfolk Sediment Cleanup Study, a shoreline survey was conducted by KCWPCD to determine the topography/bathymetry of the intertidal and shallow subtidal area, and to establish locations of river bank features (e.g., riprap, outfalls and channels, wingwall, barge).

Figure 2-3 is derived from a digitized an aerial photograph of the site taken in 1995 at approximately zero MLLW tide, and incorporates results of the KCWPCD shoreline survey. The figure shows the CSO outfall, several riverbank features, and bathymetry contours. The smaller outfalls are not visible, nor is a large rock pile located just off the first downstream wingwall.

An area upstream of the outfall was dredged for a barge dock, which remains but is not used (**Figure 2-3**). Downstream of the outfall, the lower 9.6 km (approximately) of the river is maintained as a navigable waterway (Duwamish Waterway) by the U.S. Army Corps of Engineers (ACOE). The ACOE contracted to have Turning Basin #3 dredged in March 1994, and sand from this activity was used for thin layer capping at the Port's Short Stay marina project at Pier 64/65. Turning Basin #3 is dredged approximately every 2 years. Downstream of the turning basin to the First Avenue South bridge, the navigation channel is approximately 46 meters wide and 5 meters below MLLW (Weston, 1993). Between the First Avenue South bridge and Harbor Island, the channel widens to approximately 65 meters, and deepens to approximately 10 meters.

2.4 WATER RESOURCES

2.4.1 Duwamish River

The Duwamish River begins at the confluence of the Black and Green Rivers at approximately river km 19. The Norfolk outfall is located at approximately river km 10. The river is a salt-wedge estuary, with tides influencing the river over its entire length (Dexter et al., 1981). The mean tidal range in the lower 7 km of the Duwamish River is approximately 2.3 meters. The distance upstream to the toe of the salt wedge (salinity at least 25 ppt) depends on the tidal amplitude and freshwater discharge. During periods of low flow, the salt wedge extends upstream to approximately river km 16. During periods of high flow, the salt wedge extends to river km 13 (Weston, 1993). Little mixing of the salt wedge and river water occurs (Dexter et al., 1981). The salinity of the upper river water layer increases in a downstream direction, but the salinity of the bottom layer remains fairly constant [except at the toe of the salt wedge, which is generally located upstream of the Norfolk outfall (Santos and Stoner, 1972)].

The Duwamish River at the Norfolk CSO will generally be highly stratified, with the thickness of the fresh and salt water layers varying with tides and the river discharge. The salinity at agiven depth is generally laterally constant, but the vertical distribution can vary with depth from 2 to 28 ppt (Santos and Stoner, 1972). The thickness of the interface between the fresh and salt water layers may be as little as 2 meters, or even less at low tide when the water channel depth is only 1.5 to 2 meters. Salinity measurements of interstitial waters in the study area were conducted as part of this study. Salinity ranged from 14 to 22 ppt for upriver stations, and 5 to 16 ppt for stations located adjacent to or downstream of the outfall (refer to **Chapter 4.4.1**). Salinity in the main channel sediments is expected to be closer to marine conditions because of the consistency of the salt wedge in the deeper channel.

River flow is regulated upstream on the Green River by the Howard Hansen Dam. The annual average river discharge is 47 m^3/sec, and the probable maximum flood (PMF) is approximately 400 m^3/sec. The annual suspended sediment discharge from the Duwamish River was estimated to be 1.7 x 10^3 metric tons per year, based on daily measurements of suspended sediments in the mid-1960s (Dexter et al., 1981). Recent data collected for the Elliott Bay Waterfront Recontamination Study (EBDRP, 1995d) indicates an average total Duwamish River TSS load of 7.6x10^3 metric tons per year, based on records for the 1943-1983 period.

2.4.2 Surface Water Drainage

The southern reaches of Seattle and the northern reaches of Tukwila in the vicinity of the site have been heavily modified by man. Surface water drainage patterns in the original watersheds have generally been replaced by public and private drainage systems designed to route water away from commercial, residential, and industrial properties and into either piped drainage systems or the remaining wetlands. The Cities of Seattle and Tukwila, and the Washington Department of Transportation (for I-5), are continuing to make planned upgrades to the system..

Surface drainage enters the Duwamish River in the vicinity of study area from three main sources:

- Local Outfalls
- Connections to the CSO outfall after the regulator
- CSO Events

These main sources are briefly discussed below. For a detailed description of the Norfolk surface water drainage system, refer to **Appendix J.**

2.4.2.1 Local Outfalls

Surface water runoff, including roof drains, enters nearby properties and flows either overland to the river or into small, local drainage systems with outfalls directly into the river. Five storm drain outfalls were identified during this investigation between the Norfolk CSO and the downstream concrete bridge. These storm drains are maintained by the Boeing Company, and service their facilities between E. Marginal Way and the Duwamish River. These outfalls are identified in **Figure 2-3** and **Appendix F.** These storm drains represent a fairly constant storm-related source to the river, and are not normally sampled. The Boeing Company did sample sediments at the base of these outfalls in conjunction with this study, and sample results are presented in **Chapter 3** and **Appendix F**.

A storm drain outfall located 0.4 km upstream of the Norfolk CSO serves a section of Interstate 5 (I-5). This separate drainage system is owned and operated by the Washington State Department of Transportation (WSDOT), and the 60-inch pipe is known as the Ryan Street Outfall (**Figure 2-2**). Several other facilities tie into the WSDOT line. Refer to **Chapter 3** for source control measures associated with this drainage system.

2.4.2.2 Connections to the CSO Outfall After the Regulator

Surface water runoff from properties further from the site flows into local drainage systems and then into the CSO outfall after the regulator. This storm water is not part of the King County CSO system, and is essentially using the outfall as a quick route to the river. The majority of the runoff is from commercial and light industrial systems. Some of the storm water runoff is routed through unlined drainage ditches and wetlands before reaching the outfall pipe, while other runoff immediately collects in pipes and is routed directly to the CSO outfall and out to the river. This represents a fairly constant storm-related source to the river, and does not appear to be sampled.

2.4.2.3 CSO Events

Overflow events at the Norfolk regulator are usually triggered by major storm events which overload the sewer system with storm water. Storm water in the Norfolk CSO comes from a large drainage basin in south Seattle. The area includes residential, commercial, and industrial facilities. King County has an extensive ongoing program for removing commercial and industrial storm water from the sanitary sewer system, but enough connections still exist (especially from roof drains) to overload the system during major storms. There were 25 overflow events in water year 1990/1991, but only 5 events in 1991/1992 (KCDMS, 1994b). Ongoing upgrades to King County's system will reduce the number and magnitude of these overflows (see **Chapter 3**). The CSO outfall is permitted under the NPDES program, and CSO overflows are sampled periodically to meet permit conditions (refer to **Chapter 3** for a discussion of water quality data).

2.4.3 Groundwater Drainage

The Duwamish valley is located in the central Puget Sound lowland physiographic province. The geology of the area is characterized by regional bedrock structure, glacial erosion and deposition, and fluvial deposition by the Duwamish River. Groundwater flow rates and direction in the vicinity of the Norfolk site is expected to be complex because of the presence of a filled river channel. Depth of fill in the vicinity of the site is generally less than 2 meters, except in the former river channel, where depth may be greater to create uplands (Sweet, Edwards & Associates, and Harper Owes; 1985).

2.5 ECOLOGICAL RESOURCES

2.5.1 Habitat

As part of the Norfolk Sediment Cleanup Study, a Pentec biologist performed a site visit in February 1996 to observe existing habitat conditions. Field observations are summarized below, while a detailed memorandum is included in **Appendix H**.

From the Norfolk CSO outfall downstream to the concrete bridge, riprap or rubble overgrown with blackberries predominates on the upper bank. In this same area, the lower beach is a gradually sloping intertidal mudflat. At the point of transition between the blackberries and the lower mud slope, several areas exhibit a relatively flat bench of limited saltmarsh vegetation, probably *Carex lyngbyi* and a species of *Scirpus*. Several pilings are set in the beach, and three lines of pilings are set as flow deflectors at an angle to the flow. Refer to **Figure 2-3** for shoreline feature illustration.

During the February 1996 site visit, great blue heron tracks were observed on the mudflat downstream of the outfall, and coots, a mallard duck, and a pair of American mergansers were observed along the shoreline. A few gammarid amphipods were observed in the shallow water over the mudflats, and attached epibiota were represented by a few barnacles (*Balanus glandula*) attached to rocks, rubble, and pilings. The mud itself did not appear to support significant macroscopic infaunal organisms, but was aerobic for several centimeters.

Several restoration actions could be applied at the Norfolk site that would improve the quality of the shoreline habitats for a variety of ecological functions, including juvenile salmonid feeding and migration corridors, flatfish nursery, and shorebird and waterfowl feeding. These options are discussed further in **Appendix H**.

Downstream of the project site, Turning Basin #3 and Kellogg Island are the largest remnants of intertidal habitat remaining in the Duwamish Estuary (Tanner, 1991). Potential habitat restoration projects in the vicinity of the turning basin area are illustrated in **Appendix H.** These sites include Seattle City Light North and South projects, a Kenco Marine project at Turning Basin #3, and a small site at Slip 6, located within approximately 1 km downstream (Tanner, 1991; Metro, 1993b). Potential habitat restoration sites are also located within 1.5 km upstream of the Norfolk site.

2.5.2 Fish and Wildlife

The following information has been compiled from various sources, and represents fish and wildlife species observed in various portions of the Duwamish estuary. Not all of the species discussed below may actually use the Norfolk site.

The Duwamish estuary provides nursery habitat for numerous marine fish species and juvenile salmonids. Studies conducted in the lower Duwamish River have identified over 20 marine and anadromous fish species (Parametrix, 1980). Marine fish species found in abundance include English sole, starry flounder, Pacific staghorn sculpin, shiner perch, and Pacific herring. Juvenile sole species and Pacific staghorn sculpin were found in the estuary over the entire year. Migration of spring-summer juvenile crab has also been identified in the vicinity of the Norfolk site (PTI, 1993).

The lower 10 to 13 km of the Duwamish estuary is an important transition zone for juvenile salmon to acclimate to saltwater (Parametrix, 1980). The Norfolk outfall is located within the transition zone at river km 10, and the intertidal flats located immediately downstream of the outfall on both sides of the river may provide feeding areas for fish.. The Green River (located upstream of the Duwamish) and the lower reaches of its tributaries provide important spawning habitat.

Studies have shown that of the five Pacific salmon species, chinook salmon are most dependent on estuaries during the early stages of their life cycle (Varanasi et al., 1993). Juvenile chinook salmon were found to be most abundant near Kellogg Island between April and June (Parametrix, 1982), and juvenile chum salmon were most abundant in April and May. Coho salmon have been found in fewer numbers near Kellogg Island and do not appear to use this habitat as extensively as chum and chinook salmon. The diet of juvenile chinook salmon was found to consist of copepods, amphipods, insects, annelids, and small fish (Varanasi et al., 1993).

Nine mammal species have been observed in the Duwamish River estuary (Tanner, 1991). Aquatic species include the harbor seal, killer whale, Stellar sea lion, muskrat, and river otter, while terrestrial species include the Norway rat, raccoon, snowshoe hare, and Townsend vole.

Eighty-four bird species have been observed in the Duwamish River estuary (Tanner, 1991). Kellogg Island provides important nesting habitat for birds. Nests observed during surveys conducted in the late 1970s included American goldfinch, California quail, Canada goose, gadwall, killdeer, northern oriole, red-winged blackbird, song sparrow, and spotted sandpiper (Canning et al., 1979). At the Norfolk site, as previously mentioned, waterfowl are present and use the intertidal areas along with seagulls, herons, and crows.

2.5.3 Beneficial Uses

Salmonids are considered the most commercially and recreationally important fish species using the river. Species include chinook, coho, and chum salmon, steelhead and sea-run cutthroat trout, and Dolly Varden char (Parametrix, 1980).

The Duwamish River estuary is within the usual and accustomed fishing ground of the Muckleshoot Tribe, which targets almost exclusively non-resident fish such as salmon (St. Amant, 1993). Tribal fishing occurs with river skiff gill nets (PTI, 1993). In addition to the tribal fishery, the Green and Duwamish Rivers sustain a major sport fishery for steelhead and are also popular for salmon (Grettè and Salo, 1986). The Muckleshoot Tribe and Washington State Department of Fisheries operate hatcheries located on tributaries to the Green River. The Muckleshoot hatchery produces chinook salmon, chum salmon, and steelhead trout. The state hatchery has primarily produced coho and fall chinook salmon (Grette and Salo, 1986).

3.0 SOURCE CONTROL EVALUATION

3.1 POTENTIAL CONTAMINANT SOURCES

The following section briefly discusses potential contaminant sources near the Norfolk study area.

3.1.1 Boeing Stormdrain Outfalls

Between the Norfolk CSO outfall and the downstream concrete bridge, five storm drains that collect surface water runoff from adjacent Boeing property discharge to the Duwamish River. These outfalls are connected to a stormwater drainage system owned and operated by the Boeing Company.

Limited sampling of surface sediments at the base of each storm drain outfall was conducted by Boeing in March 1996, and samples were tested for PCBs. Results for four samples were nondetectable at 0.05 mg/kg dry weight (DW), while PCBs were detected at one station at 0.19 mg/kg DW. **Figure 2-3** and **Appendix F** present locations of the Boeing storm drains, and **Appendix F** includes the Boeing PCB sampling results. PCBs were chosen as the chemical of concern for these sediments because of the elevated PCB concentrations detected in the mudflat sediments in front of these outfalls (and downstream of the Norfolk CSO). The one-time sampling of these outfalls indicates that PCBs are not currently discharging from these outfalls, but may have in the past. Unconfirmed information indicates that portions of the adjacent Boeing parking lot were at one time used by an equipment salvage company for storage of large industrial equipment (Steve Ryan, personal communication).

3.1.2 Norfolk Combined Sewer Overflows

During the 1990/1991 water year, 25 overflow events were recorded at the Norfolk CSO outfall. These events released a combined overflow volume of 169 MG of untreated sewage and stormwater. During the 1991/1992 water year, only five overflows were recorded with a combined overflow volume of 8 MG (KCDMS, 1994b). Overflow volumes of CSO discharges were estimated to average 70 MG per year (EBDRP, 1996). Potential contaminants from the CSO include untreated sewage from the sanitary sewer, as well as sediment, oils and other contaminants from industrial wastewater and stormwater runoff. As discussed in **Chapter 1**, chemicals of concern based on preliminary sediment samples collected near the Norfolk CSO outfall include mercury, 1,4-dichlorobenzene, bis (2-ethylhexyl) phthalate, PCBs, and benzoic acid; while a CSO water sample collected in 1993 contained a few organic chemicals(benzylbutylphthalate, diethylphthalate, acetone, and tetrachloroethylene). This preliminary data is presented in **Appendix A.**

Since mid-1996, the Henderson diversion structure, which is part of the Southern Transfer Project (refer to **Section 3.3**) has been in operation in the Norfolk Basin. The structure will divert 19 MGD from the Norfolk Basin to the Renton Treatment Plant, which will significantly reduce the number and size of overflows at the Norfolk regulator.

3.1.3 Stormwater Connections to the Norfolk CSO Outfall

In addition to the CSO overflow events, there are five storm drain lines that connect to the CSO after the regulator. Four of the five lines service very small drainage areas and roofs. The fifth line is believed to collect stormwater from E. Marginal Way, the southern end of King County International Airport (KCIA), and adjacent facilities. Stormwater from these five lines has the potential to be contaminated with oil and grease, road dust, and other chemicals used at the facilities.

3.1.4 Industrial Sites

The Norfolk Basin contains both light and heavy industry. Wastewater and roof-drain stormwater from these facilities could contribute to overflow events, and would explain the appearance of solvents and phthalates in the water sample from the CSO (**Appendix A**). However, stormwater contributions from those facilities that are connected to the outfall after the regulator (**Chapter 3.1.3**) are expected to be a more constant source of potential contaminants.

Ecology's list of Confirmed and Suspected Contaminated Sites (E. Atkinson, Ecology, personal communication, 1993) included the Yellow Freight Terminal (petroleum products), located within 1 km upstream of Norfolk; and the Northwest Auto Wrecking Site (metals and petroleum products), located in the immediate vicinity of the Norfolk outfall. None of the Boeing properties along this section of the Duwamish were listed.

3.1.5 WSDOT I-5 Outfall (Ryan Street Outfall)

The WSDOT owns and operates a separate storm drainage system that serves the section of I-5 between the Boeing Access Road (the continuation of S. Ryan Way) north to S. Myrtle Street. Known as the Ryan Street outfall (**Figure 2-2**), the 60-inch pipe flows west from I-5 along the City limits, and outfalls to the Duwamish River 0.4 km upstream of the Norfolk CSO.

Since 1992, when the City connected their system to the WSDOT system, significantly more stormwater has discharged from this outfall. Additional projects including major renovations to the line and the addition of retention ponds are currently under construction in the system. These improvements are expected to result in improved water quality and more controlled flows.

Sediments upstream of the Norfolk CSO outfall are currently below SMS criteria (refer to **Chapter 5**); therefore, the Ryan Street outfall is not considered a historical source of contamination to the study area. Planned improvements and upgrade are expected to maintain the water quality upstream of the Norfolk CSO outfall.

3.1.6 Groundwater

Groundwater quality in the area is not well documented. Shallow groundwater flow is expected to be very complex due to the number and location of utility corridors in the area, and to the presence of a former river channel that has been filled. Groundwater is not expected to be a major source of contamination to the sediments, primarily because the sediment contaminants of concern are normally associated with CSO discharges.

3.2 COMBINED SEWER SYSTEM

3.2.1 Overview

From the early 1900s to the mid-1940s or later, combined sewers were built to collect both sanitary sewage and stormwater in the Henderson, M. L. King, and Norfolk drainage basins. These combined sewers have been adequate for conveying dry-weather flows, but are inadequate to handle flows from heavy rain storms. When flows exceed the pipe and pumping capacity, the excess flow discharges directly into the receiving waters as CSO at overflow structures.

In the late 1950s, Metro was established to develop a regional approach to the conveyance and treatment of sanitary sewage from the Seattle area. The City of Seattle transferred parts of the combined sewer system in its Southern Service Area to Metro, including interceptor sewers in the Henderson, M. L. King, and Norfolk drainage basins. Metro (now KCWPCD) provides conveyance and treatment services for the sewer systems in these basins, and the City of Seattle maintains its own sewer collection system. Since the 1960s, KCWPCD and the City of Seattle have been constructing projects (including CSO control projects) in the Southern Service Area to improve water quality.

KCWPCD oversees an extensive configuration of conveyance pipelines, regulator stations, and other wastewater facilities (KCDMS, 1995a). KCWPCD's pipelines consist of force mains, trunk sewers, and interceptors. KCWPCD trunk sewers pick up flows from the small collection pipelines and convey them to large diameter interceptors that serve as the conduits for transferring flow to the treatment facilities. After treatment, treated effluent is conveyed through outfall pipes to Puget Sound.

Combined sewer overflows serve as safety valves for the sewer system. In combined sewer systems, the trunk sewers and interceptors have fixed capacities while wastewater flows vary with precipitation. During periods of intense or prolonged precipitation, wastewater volumes may exceed the capacity of the sewer pipes to convey that wastewater to the treatment plant. In order to prevent damage to the treatment plant and backup of wastewater into homes and businesses, the lines are designed to overflow into receiving waters. The control point for overflows occurs at the regulator station.

Regulator stations were constructed by Metro in the early 1970s as a means of controlling CSOs. Regulator stations maximize the storage potential available in the large diameter trunk sewers by shutting off flow to the interceptors during conditions of high storm flows. As a result, wastewater is forced to back up in the trunks. When the trunk reaches its specified storage capacity, an overflow gate is opened and the trunk flows are released through an outfall structure as combined sewer overflow. A typical regulator station is illustrated in **Figure 3-1**.

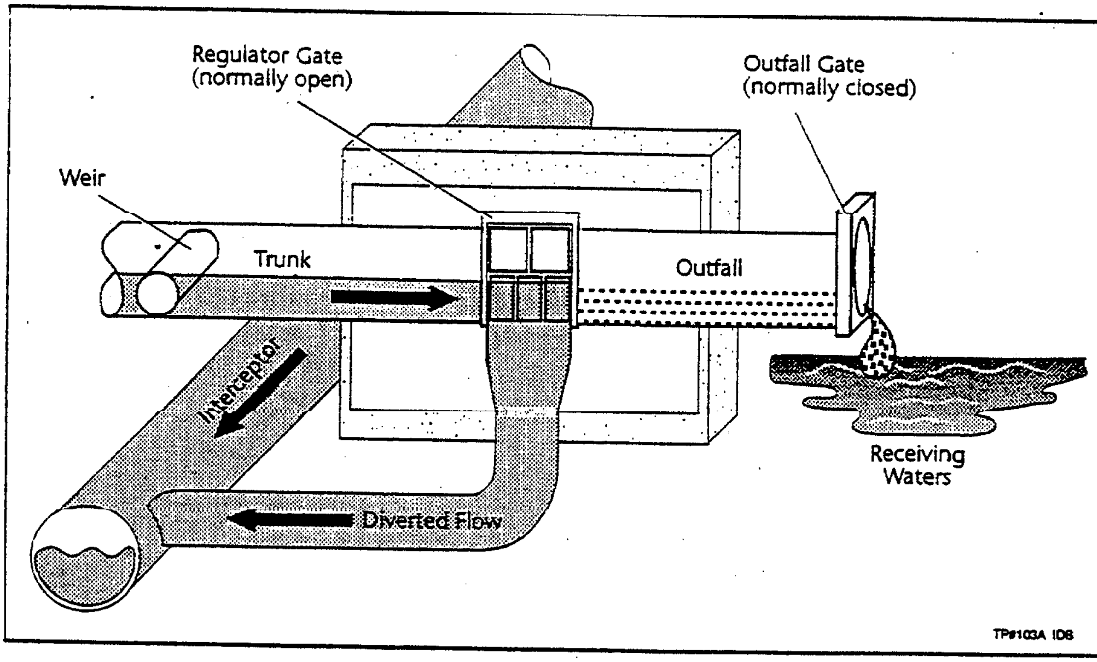


Figure 3-1

Norfolk CSO Sediment Cleanup Study
TYPICAL REGULATOR STATION

3.2.2 Regulations and Planning

Metro instituted a formal CSO control program in 1979 under the impetus of the Federal Water Pollution Control Act Amendments of 1972 (KCDMS, 1995a). In 1987, Washington Administrative Code (WAC) 173-245 went into effect under the administration of the Department of Ecology, requiring reduction in CSO volumes to an average of one untreated discharge per year at each outfall. WAC 173-245 also requires CSO plans specifying the means of complying with the regulation. KCWPCD and the Department of Ecology developed an interim goal of achieving an overall reduction of 75 percent CSO volume throughout the KCWPCD jurisdiction by the end of the year 2005. The *1988 Combined Sewer Overflow Control Plan* (Metro, 1988) was developed to implement these CSO reduction goals. The *Combined Sewer Overflow Control Plan 1995 Update* (KCDMS, 1995a) describes the current status and revised future plans.

3.3 SOURCE CONTROL IMPROVEMENTS

If sediments around the Norfolk outfall are remediated, adequate control of sewer overflows, storm drains, and industrial sources is a necessary prerequisite to preventing sediment recontamination. System improvements, as well as source controls, have been implemented and are described below.

3.3.1 CSO Volume Estimates

In several of KCWPCD's CSO reports, overflow volumes at the Norfolk Regulator have been estimated. These estimates are based on detailed models developed by KCWPCD, and the estimates have changed over time because of improvements in the models, additional information on the watershed, and the natural variation in rainfall intensity. Best estimates are that the Norfolk outfall discharged between 60 and 70 MG per year, on average, in overflows during the late 1980s and early 1990s.

3.3.1.1 Runoff/Transport Modeling Results

To assist in the design of system improvements, existing CSO volumes and the number of CSO events per year were estimated for the Norfolk Regulator. Seventeen years of historical precipitation records were used as input to Metro's Runoff/Transport model (KCDMS, 1995b). The modeling produced a continuous simulated record of flows. A design storm statistically representative of the one-year storm was modeled, and the potential improvements were sized to achieve a flow rate of one untreated CSO event per year.

3.3.2 The Southern Transfer Project

The single most important improvement to date for the Norfolk CSO has been the construction of the Southern Transfer Project. The Project consists of the Henderson Diversion Structure and pipe connections that divert up to 19 MGD of wastewater from the Norfolk area to the Renton Treatment Plant via the Allentown Trunk and the Interurban Pump Station (see **Figure 3-2**).

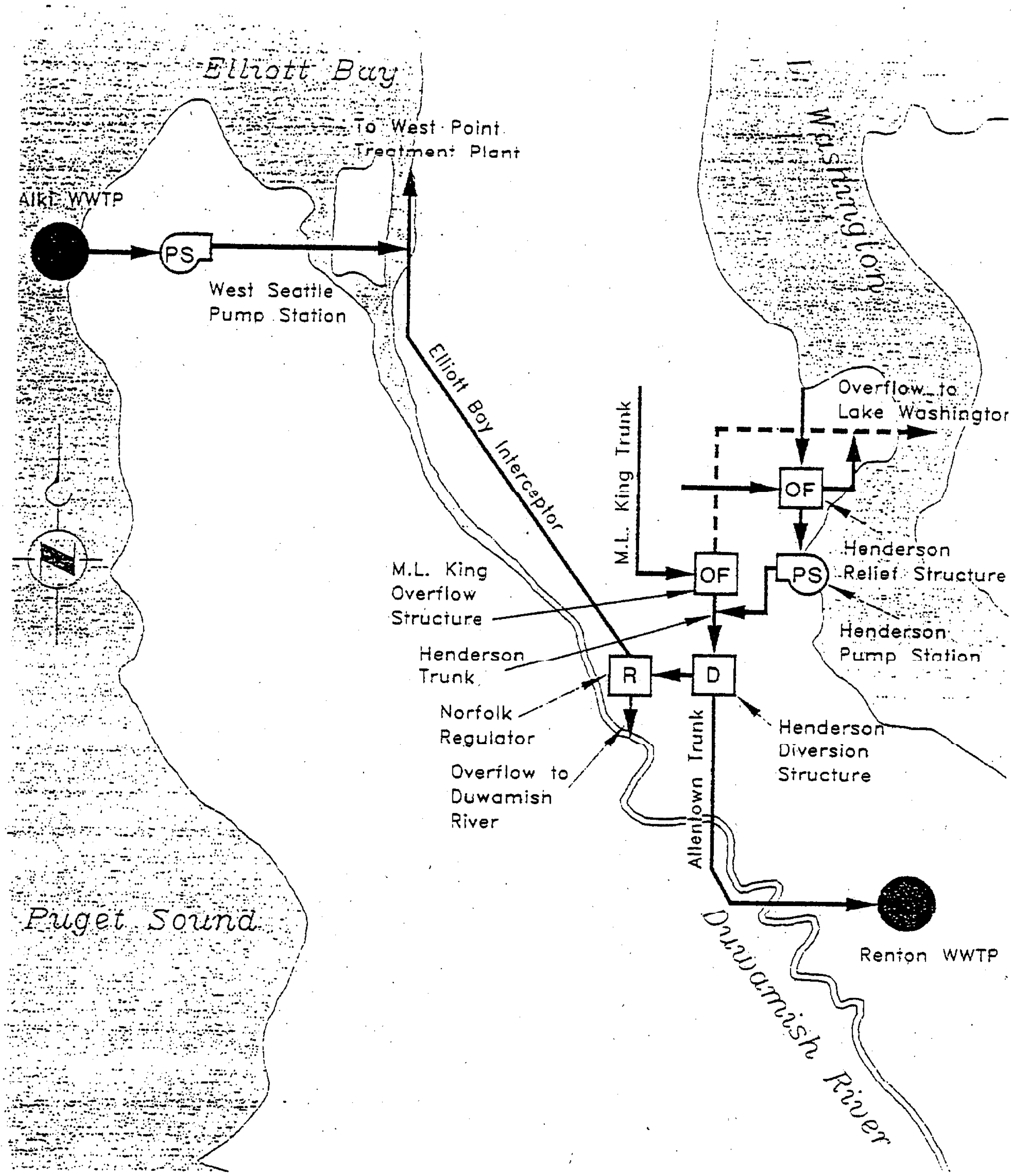


Figure 3-2

Norfolk CSO Sediment Cleanup Study
HENDERSON/M. L. KING SYSTEM SCHEMATIC

Source: Henderson/M. L. King Project, 1995, L&A Associated Firm.

Beginning in mid 1996, KCWPCD commenced testing of the Southern Transfer Project. When fully operational in 1997, it is estimated that this project will reduce overflow incidences at the Norfolk Regulator to about four events per year and about 7-9 MG in annual overflow volume (**Table 3-1**). It should be noted that additional City of Seattle storm drains connected to the 84-inch-diameter outfall downstream of the regulator make flow estimates approximate.

Table 3-1
EFFECTS OF THE SOUTHERN TRANSFER ON THE NORFOLK CSO

Flow Description	CSO Volume (MGY)	CSO Frequency (Events Per Year)
Annual CSO frequency and volume without Southern Transfer at the Norfolk Regulator	70	19
Annual CSO frequency and volume with Southern Transfer	7 to 9	4

3.3.3 Henderson/M. L. King CSO Project

The *1995 CSO Plan Update* (KCDMS, 1995a) identifies the Henderson and M. L. King basin project as one of several projects to reduce CSOs throughout KCWPCD's Southern Service Area. When constructed, this project will divert wastewater flows form the Henderson and M. L. King CSOs, which discharge into Lake Washington, and divert them to the Norfolk Regulator. Protecting sensitive fresh-water systems like Lake Washington from CSOs has been identified as a high priority. However, the capacity of the EBI and the Southern Transfer Project are not enough to divert a one-year storm flow from the Henderson and M. L. King CSOs to either the West Point or Renton Treatment Plants. Therefore, the Henderson/M. L. King Project includes options for the construction of CSO treatment and/or storage facilities at the Norfolk Regulator. Under the storage and treatment options, the discharge volume at the Norfolk outfall could be greater than 7 to 9 MGY. However, the additional discharge would be treated effluent rather than untreated CSO. One option estimates that 50 MGY will be discharged at Norfolk with 50 percent treatment. The specific volume and treatment efficiency of the storage/treatment system will be modeled during the predesign phase of the project, and the quality of the treated discharge will be designed to avoid recontamination of the sediment remediation project performed offshore of the Norfolk outfall. CSO control project goals are summarized in **Table 3-2**.

Table 3-2
HENDERSON/M. L. KING CSO CONTROL PROJECT GOALS

Goals
• Reduce Henderson and M. L. King CSOs to no more than one untreated event per year.
• Do not increase CSOs at Norfolk. It is preferred to reduce to one untreated CSO event per year, but not required.
• Accomplish CSO goals without exceeding the 19 MGD flow created in the Allentown Trunk by the Southern Transfer Project in the year 2005; interim flows up to 23 MGD are permissible.

3.3.4 Infiltration/Inflow Sources

The Runoff/Transport model using the one-year storm was run to identify subbasins where infiltration/inflow (I/I) is a relatively high percentage of total flow. The identified subbasins were then investigated to determine whether full flow separation, including rooftop disconnection, would be cost-effective.

Newly developed areas are built with fully separated systems. When roof drains, footing drainage, and catch basins are connected to the storm drain system, and sanitary sewer pipes and manholes are new, there is little infiltration. Retroactive separation, such as the partial separation done in the City of Seattle beginning in the late 1960s, typically yields about 30 percent impervious area connected to the sanitary sewer, and 0 percent pervious area connected. In the partial separation projects completed in the Henderson and M. L. King basins by the City of Seattle, new storm sewers were constructed, and catch basins were reconnected to the storm sewers; however, roof drains were left connected to the sanitary sewers. One privately-owned combined sewer from the 350-unit Seward Park Estates apartment complex is scheduled for separation in 1997.

Existing I/I in the Norfolk Basin is believed to be primarily from direct roof connections to the sanitary sewer system. Flow monitoring should be continued in the basin for identification and quantification of CSO sources.

3.3.5 Watershed Source Controls

Source control within the Norfolk drainage basin is also being implemented. The City of Seattle Drainage and Wastewater Utility (DWU) completed business inspections in the Norfolk drainage basin in May 1996 (**Appendix I**). Approximately 85 businesses in the basin were targeted for windshield or on-site inspections. The objective of these inspections was to control contaminant input from upland drainage basins by promoting best management practices, including disposal/storage activities, and increased local awareness of protecting water quality. To identify potential contaminant sources to the drainage system, the DWU reviewed existing business practices, monitoring information, historical storm system maintenance, and previous investigations.

Sediments in the discharge pipe are also a potential contaminant source that may recontaminate sediments. The DWU has identified sediment removal from storm lines as a method of reducing contaminant input to the Duwamish River, and the Seattle Engineering Transportation Department has the responsibility for maintaining the storm lines, catch basins, and inlets in the city. DWU reviewed maintenance records for storm structures, and estimated that approximately 500 inlets are within the Norfolk basin boundaries. Historical maintenance records document annual inspections of inlets for sediment depth, with scheduled pump-outs usually on alternate years. The DWU last surveyed the Norfolk storm drain system in 1995 and did not find sediment in the line (**Appendix I**).

Finally, WSDOT improvements to their drainage system will help control contaminants that could discharge from their outfall, upstream of the Norfolk CSO.

3.4 RECONTAMINATION MODELING RESULTS

Sediment recontamination modeling was conducted by KCWPCD (EBDRP, 1996) to evaluate the likelihood of recontamination of the sediment at the site after sediment cleanup has occurred. The approach was to model the potential increase in sediment concentrations of various contaminants in the cleaned area in the vicinity of the discharge. If modeling results indicate the potential for recontamination, additional source control measures would be necessary in the Norfolk basin.

The model used for the evaluation is based on SEDCAM (Ecology, 1991). It was modified by KCWPCD staff and renamed METSED. METSED assumes that chemicals discharged to the receiving water (the Duwamish River) are well mixed in a control volume overlying the sediments. Knowing the ambient flow of water and concentrations of chemicals entering the control volume, and the CSO discharge and discharge concentrations of the same chemicals, the model computes the exchange between the water column and the underlying sediment to calculate sediment concentrations. Processes modeled include mass accumulation, constituent decay, sediment diffusion, and chemical partitioning.

In applying METSED, it was assumed that the discharge from the CSO would mix into a fraction of the Duwamish River, characterized by a mixing zone width. Three characteristic widths were evaluated: (1) a theoretical mixing zone width of 0.3 feet developed from a momentum dissipation analysis of the CSO discharge, (2) 100 feet, representing the width of the observed contamination footprint, and (3) 325 feet, the width of the Duwamish River at the Norfolk outfall site. Particle size distributions from samples taken in the Green River were used to estimate settling velocities, and the average discharge in the Duwamish River was assumed to have a constant discharge per unit width.

The model was run to simulate both the historic discharge and the estimated discharge following CSO reduction. The model was run in two modes. In the first mode, the discharge from the CSO was assumed to be the annual average. In the second mode, the time-varying discharge was divided into 52 weekly-averaged discharges. The model results were presented as sediment concentrations for each of the CSO discharges, discharge modes, and characteristic mixing zone widths, and compared against sediment quality criteria. The results were also presented as the minimum mixing zone width needed to achieve compliance with the sediment quality criteria for each of the chemicals evaluated.

Model results (**Table 3-3**) show that the minimum mixing zone width needed for compliance with SQS criteria decreases from a maximum of 16 feet (for butyl benzyl phthalate) for the historic discharge to less than 1 foot for the reduced CSO discharge (with most of the chemicals evaluated requiring significantly less than one foot of mixing zone width). Even though the theoretical mixing zone width for the reduced CSO discharge is 0.3 feet based on momentum dissipation calculations, the actual width is likely to be significantly larger when other factors such as varying current directions and lateral spreading during particle settling are also considered. Therefore, the strategy of reducing the discharge from the Norfolk CSO outfall should not cause recontamination of sediments in the vicinity of the discharge.

Table 3-3
RESULTS OF METSED RECONTAMINATION MODELING

Compound	CSO Concentration (µg/L)	SQS (µg/kg)	Minimum Width to Achieve Cmix = Csqs	
			Pre-1995/96 Discharge	Reduced Discharge
Arsenic	1.19	57,000	<1	<<1
Cadmium	0.1	5,100	<1	<<1
Chromium	9.0	260,000	<1	<<1
Copper	33.25	390,000	<1	<<1
Lead	26.06	450,000	<1	<<1
Mercury	0.38	410	<1	<<1
Nickel	5.13	NA	--	--
Silver	0.3	6,100	<1	<<1
Zinc	114.25	410,000	<1	<<1
Bis(2-ethylhexyl) phthalate	0.25	47,000	0.8	<1
Butyl benzyl phthalate	0.82	4,900	16	<1

Notes:
NA: Not available.

A second approach to evaluate the reduction in chemical concentrations in the sediment is to scale the sediment concentrations measured in the zone of sediment criteria exceedance by the ratio of the constituent mass discharge of each chemical following source control divided by the existing mass discharge of the same chemical. This approach assumes (1) that the width of the dilution zone following CSO discharge reduction remains the same, and (2) that the equation (in METSED) describing the mass transfer between the control volume and the underlying sediments, including losses, is linear and can be scaled by constituent concentration. Both of these assumptions, while not strictly correct, are accurate enough for a screening-level assessment. The ratio of the mass discharge following source control divided by the existing mass discharge is approximately 0.10 (70 MG to 7 MG). Multiplying constituent concentrations by this ratio results in concentrations that are below SQS criteria, for all chemicals except PCBs. This supports the conclusion of the sediment recontamination modeling that reductions in CSO discharges are sufficient to control and limit recontamination from the CSO.

Neither modeling approach directly addresses PCB recontamination. PCBs have been analyzed for in the CSO, but have never been detected. PCB distributions in the sediments indicate that the source(s) may be historical (i.e., concentrations are higher in the 1- to 2-foot depth of the cores compared to surficial layer).

The major limitations in the recontamination modeling are as follows:

1. The model assumes mixing in the river. This is a reasonable assumption whenever the river height is above the outfall, or where the outfall's water exits the channel in the mudflat and enters the major channel of the river. This model does not account for movement of the outfall's water across the mudflat when the river level is just above the level of the mudflat. Consequently, localized contamination to the mudflat near the outfall may be worst than predicted.

2. The model does not account for possible contamination from the Boeing stormdrain outfalls. Because sediments at the base of the outfalls are currently clean and the outfalls drain primarily parking lots and roof drains in areas where contamination is not expected, these outfalls are not expected to be a major source of contamination in the future. However, future monitoring of the outfalls and/or sediments is likely warranted.

3. The model does not account for PCB contamination at the hotspots associated with Stations 305 and 315. The source of the PCBs in these hotspots is not known. It is believed to be historical rather than on-going, and is not necessarily connected with the Norfolk outfall. Consequently, there was no way to incorporate the PCB hotspots into the model.

4. The model does not account for tidal effects on the discharge. Tidal effects are not expected to lower the mixing, except as described in 1 above; and will increase mixing during the higher portion of the tidal cycle. The net effect, while not modeled, is not expected to significantly change the model results.

5. The model does not account for stormwater discharge from sources connected to the Norfolk outfall <u>after</u> the regulator. The quantity and quality of this stormwater is not known, but based on known land use, it is probably similar in content to the CSO (e.g., iron, suspended solids, oil & grease, but not 1,4-dichlorobenzene, which is a marker for sanitary inputs). The mixing zone in the model appears to be adequate to account for this additional source of contaminants, but that will need to be confirmed with future monitoring of the stormwater discharge and/or sediments.

Overall, the recontamination modeling results and back-of-envelope calculations indicate the potential for sediment recontamination is minimal. Monitoring will be conducted following cleanup to confirm that sediments are not being recontaminated from current discharges.

4.0 DATA COLLECTION AND RESULTS

4.1 STUDY OBJECTIVES

The overall objective of the data collection effort was to characterize the spatial extent and magnitude of sediment contamination resulting from historical discharges of the Norfolk CSO outfall into the Duwamish River. Field sampling was conducted by KCWPCD staff over three phases. Specific objectives of each phase are summarized in **Table 4-1** below.

Table 4-1
STUDY OBJECTIVES

Phase	Sample Period	Primary Objectives
1	August 17-31,1994	1a. Determine the areal extent of sediment contamination around the outfall based on comparison of surface chemistry data to SMS criteria; supplement analysis with bioassay data.
2	August 23-28, 1995	2a. Refine the boundary of the sediment cleanup area around the outfall based on additional surface chemistry characterization. 2b. Collect sediment cores to determine vertical extent of contamination. 2c. Perform waste characterization testing of sediments for disposal purposes. 2d. Conduct a shoreline beach survey to map the topography of intertidal/upland areas and locate shoreline features.
3	December 5-6, 1995	3a. Conduct a focused investigation to define the PCB boundary in downstream surface sediments near the Boeing stormdrain outfalls.

4.2 FIELD AND LABORATORY METHODS

This section briefly describes the field and laboratory methods performed during the Norfolk CSO outfall characterization. For a detailed description of study design, field procedures, and analytical methods, refer to the following documents:

- *Norfolk Sampling and Analysis Plan.* Prepared by King County Department of Metropolitan Services for Elliott Bay/Duwamish Restoration Program. EBDRP September 1994.
- *Norfolk Sampling and Analysis Plan. Phase 2 Addendum.* Prepared by King County Department of Metropolitan Services for Elliott Bay/Duwamish Restoration Program. EBDRP August 1995.
- *Norfolk Sampling and Analysis Plan. Phase 3 Addendum.* Prepared by King County Department of Metropolitan Services for Elliott Bay/Duwamish Restoration Program. EBDRP December 1995.

The *Norfolk SAP/Addenda* were developed in accordance with requirements of the SMS and the *Sediment Cleanup Standards User Manual* (Ecology, 1991). The documents were reviewed and approved by the SRTWG and the EBDRP Panel prior to implementation and are publicly available in the Panel records and public repositories.

4.2.1 Field Methods

All field sampling was performed by KCWPCD staff. In addition, Ecology staff assisted with Phase 3 sampling, and contracted personnel were utilized for sediment coring during Phase 1 and Phase 2. Specific elements of the field studies are summarized below.

4.2.1.1 Sampling Design

The sampling design for the Phase 1 sediment chemistry surface grab stations was based on depth contour strata and systematic spacing. Three strata were chosen that run approximately parallel to shore: 1) intertidal mudflat between the riprap shoreline and the 0-foot (MLLW) contour; 2) the shallow subtidal area (0 to -4 feet MLLW); and 3) the deeper subtidal area (-4 to -6 feet. MLLW) From the outfall, the sampling grid extended approximately 200 feet upstream, downstream, and offshore.

A focused sampling design was applied for the Phase 2 field effort, in order to refine the boundaries of the contaminated area. This field effort focused on the intertidal and shallow subtidal strata of the original systematic-stratified sampling area. The new station NFK 201 was added to refine the northwest boundary of the intertidal strata, while stations NFK 204 and NFK 206 were added to refine the southern boundaries of the cleanup area. Station NFK 202 was set near a local stormdrain outfall. Four core stations were taken to determine depth of sediment contamination, and were located through the proposed minimum cleanup area (based on Phase I results).

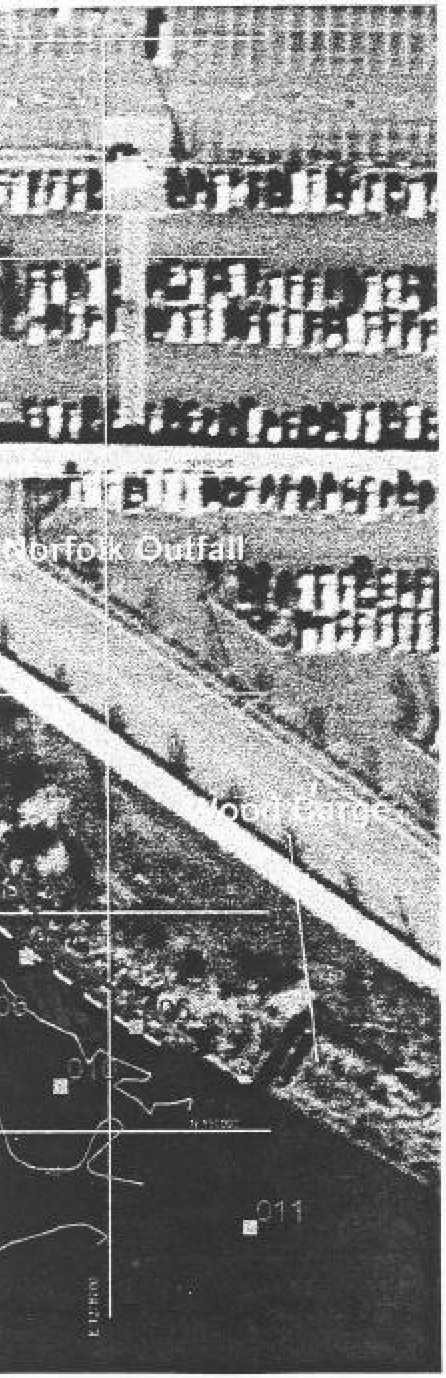
A focused sampling design was also applied for the Phase 3 field effort, in order to define the PCB boundary downstream of the originally proposed cleanup area. The Phase 3 effort focused on the intertidal and shallow subtidal zones. No sediment cores were collected.

Station locations for Phase 1 (NFK001-NFK016), Phase 2 (NFK201-NFK206) and Phase 3 (NFK301-NFK315) are illustrated in **Figure 4-1.** Overall, a total of 40 surface sediment stations and 5 sediment core stations were sampled during this investigation. Actual station coordinates and sediment elevations are presented in **Appendix E.**

4.2.1.2 Surface Sediment Collection

Surface sediment chemistry and bioassay samples were collected with a 0.1 m^2 van Veen grab. A 10-cm deep subsample from the center of the grab sample was taken for analysis. For Phases 1 and 2, two or more grabs were composited at each station to form one sample. For the Phase 3 focused investigation, only one sediment grab was collected at each station. Samples were rejected if they failed to meet sample acceptability criteria specified in *Puget Sound Estuary Program Protocols* (PSEP, 1991), and the *Norfolk Sampling and Analysis Plan/Addenda.*

EcoChem Team	Norfolk Sedim
	Ba



Outfall Flow Channels
Approximate Rock Pile
Low TOC Stations
Sample Stations
Property Line
Toe of the slope
Approximate Mean low 0
Wingwall
Bathymetry
Grid
Text Northings & Eastings

- Photo copyright 1996 City of Seattle.
- Bathymetry from David Evans & Assoc.
- Property Line from King County Engineering Dept. Map, 1994
- Other data from KCWPCD

Cleanup Study	Figure 4-1
Map	

Sediment grab samples were processed according to the following sequence, when applicable:

- Acid volatile sulfides and pH/Eh/temperature measurements were conducted on the first acceptable grab.
- The top 10 cm were then composited from several grabs.
- Sample containers were then filled in the following order from the composite: (a) methyl mercury; (b) metals; (c) BNA/pesticides/PCBs; (d) chlorinated benzenes; (e) percent solids and total organic carbon; (f) particle size distribution; (g) interstitial salinity; and (h) bioassays.

Samples were kept onboard in ice chests and transported to the KCWPCD laboratory at the end of each field day, where they were stored in accordance with conditions specified in the *Norfolk SAP*.

The van Veen grab sampler was cleaned between stations using the following sequence: 1) soap and water scrub, 2) triple rinse with site water, and 3) final in-stream site water rinse. These procedures were an exception to the *Puget Sound Protocols*, but were implemented to avoid the use of both acetone and methylene chloride in the field. Stainless steel bowls and utensils were cleaned at the laboratory prior to field use.

4.2.1.3 Subsurface Sediment Collection

Sediment cores were collected by one of two methods. During Phase 1, a single core (2-foot length) was collected by diver-operated pneumatic jackhammer, and divided into 15 cm (0.5-foot) sections for analysis. During Phase 2, four deeper cores were collected by Marine Sampling Systems, Inc., operating a hydraulic impact corer aboard the *R/V Nancy Anne*. For comparison to SMS criteria, Phase 2 cores were divided into 30 cm (1-foot) sections (i.e., 0- to 1-foot, 1- to 2-foot, 2- to 3-foot, and 3- to 4-foot) for analysis. For waste characterization purposes, Phase 2 cores were also composited into 60 cm (2-foot) sections (i.e., 0- to 2-foot, 2- to 4-foot, and 4- to 6-foot) for analysis.

Core sections were assigned unique laboratory numbers. Samples were kept onboard in ice chests and transported to the KCWPCD laboratory at the end of each field day, where they were stored in accordance with conditions specified in the *Norfolk SAP*.

All coring equipment was cleaned prior to field sampling. Core tubes were cleaned using the following sequence: 1) soap and water scrub; 2) triple rinse with tap water; 3) final in-stream site water rinse.

4.2.1.4 Reference Stations

Four reference sediments were collected by KCWPCD during Phase 1 to assist with bioassay interpretation. Two reference stations (NFKUPRIV1, NFKUPRIV2) were selected from the Duwamish River upstream of the outfall, where interstitial salinities and grain sizes would be similar to test sediments, but where sediment quality was unknown. These upstream stations were also used to establish sediment chemical concentrations upgradient of the Norfolk outfall.

The other two reference stations (CAR002, CAR004) were established at Carr Inlet, an area with known sediment quality and successful toxicity reference sediments, but where interstitial salinities will differ from the test sediments.

4.2.1.5 Station Positioning

The survey vessel was directed by shore-based surveyors to pre-determined sampling stations. Surveyors used a combined theodolite and infra-red electronic distance measuring instrument (EDMI) manned at shore reference stations. The EDMI targeted onto an Omni prism cluster mounted on the survey vessel, and the survey vessel was directed to within +/- 3m of the pre-determined station. A buoy was then deployed, and the surveyors recorded the position of the vessel after the grab sampler (or diver) hit bottom. Measured angles and ranges were converted to horizontal plane coordinates referenced to the Washington coordinate system, north zone, 1983 North American Datum (NAD83). Depths are referenced to MLLW, with corrections from a staff gage installed at the Norfolk CSO (during bathymetry survey) and corrections based on tide tables (during field sampling). During Phases 2 and 3, a staff gage was not installed, and tide corrections were determined by tide chart. River height was determined by accessing the U.S. Army Corps of Engineers flow monitoring gage.

4.2.1.6 Field Documentation

KCWPCD sample documentation included 1) Chain-of-custody forms which were maintained throughout the laboratory analyses, and 2) Fieldsheets and Sampling Notes. Field documentation is maintained on file at KCWPCD.

4.2.2 Laboratory Methods

Laboratory methods were selected to provide data for comparison to SMS criteria. In addition, sediments were tested for waste classification to evaluate disposal and beneficial use options (**Appendix K**). The KCWPCD Environmental Laboratory of Seattle, Washington, conducted most of the chemical testing. KCWPCD also subcontracted some analyses to the following laboratories: (1) Beak Consultants of Kirkland, Washington; (2) AmTest Inc. of Redmond, Washington; and (3) Frontier Geosciences of Seattle, Washington. **Table 4-2** summarizes test methods and laboratories used for this study. Since all test methods were not conducted during each phase, a complete sample inventory log of analyses performed at each station during each phase is included in **Appendix B.**

The *Norfolk SAP* specified holding times to be observed for this project. Holding times were based primarily on Ecology guidance originating from the *PSSDA Third Annual Review Meeting* (ARM, 1991).

The *Norfolk SAP* also specified detection limits to be observed for this project. The KCWPCD lab distinguished between a Method Detection Limit (MDL) and a Reporting Detection Limit (RDL) for most analyses. The MDL represents the lowest concentration at which sample results will be provided, whereas the RDL is defined as the minimum concentration of a constituent that can be reliably quantified. For this report, the MDL value was used to represent the limit of detection.

The bioassay test organisms and methods were selected based on interstitial salinity values of 3 to 9 parts per thousand (ppt) measured at the site during pre-Phase 1 investigations (**Appendix A**). West Beach sand was collected from Whidbey Island, Washington, for use as a negative control in the polychaete test. Native sediment from Yakuina Bay, Oregon, was used as the negative control for the amphipod test. Sea water was used for the negative control for the echinoderm test.

Table 4-2
LABORATORY METHODS

Parameter	Method	Laboratory
Conventionals:		
Acid Volatile Sulfides (AVS)	PSEP	AmTest
Total Solids	SM 2540-B	KCWPCD
Total Organic Carbon (TOC)	SM 5310B, PSEP Prep	KCWPCD
Particle Size Distribution (PSD)	PSEP/ASTM 422	AmTest
Interstitial Salinity	Refractometer	Beak
Metals:		
Total Metals	EPA 3050/6010; ICP	KCWPCD
Total Mercury	EPA 7471; CVAA	KCWPCD
Methyl Mercury	In-house method	Frontier Geosciences
Organics:		
Base/Neutral/Acid Extractable (BNAs)	EPA 3550/8270	KCWPCD and ARI (Phase 3 split samples)
Polychlorinated Biphenyls (PCBs)	EPA 3550/8080	KCWPCD
Chlorinated Pesticides	EPA 3550/8080	KCWPCD
Chlorinated Benzenes	EPA 3550/8270; and ion trap detector or SIM	KCWPCD
Waste Characterization:		
Total Petroleum Hydrocarbons	WTPH-HCID	KCWPCD
TCLP-Volatiles, BNAs, Pesticides, Metals	EPA SW-846	KCWPCD
Reactivity-Cyanide and Sulfide	EPA SW-846	AmTest
Ignitability and Corrosivity	EPA SW-846	AmTest
Bioassays:		
Amphipod (*Eohaustorius estuarius*)	10-d mortality; PSEP 1994	Beak
Echinoderm *(Dendraster excentricus)*	larval mortality /abnormality; PSEP 1994	Beak
Polychaete *(Neanthes arenaceodentata)*	20-d growth; PSEP 1994	Beak

4.3 QUALITY ASSURANCE/QUALITY CONTROL RESULTS

A Quality Assurance (QA) review was prepared by the KCWPCD Environmental Laboratory for data collected and analyzed during Phases 1 through 3. The QA1 reviews were conducted in accordance with guidelines established through the Puget Sound Dredged Disposal Analysis (PSDDA) program, primarily in the *PSDDA Guidance Manual, Data Quality Evaluation for Proposed Dredged Material Disposal Projects*. Additionally, many of the approaches incorporated in the QA1 reviews have been established through collaboration between KCWPCD and Ecology's Sediment Management Unit.

The chemical data were reviewed for the following parameters, where applicable: 1) completeness; 2) methods; 3) target list; 4) detection limits; 5) holding times and conditions; 6) method blanks; 7) standard reference materials; 8) replicates; 9) units and significant figures; 10) matrix spikes; and 11) surrogates. The bioassay data were reviewed for: 1) completeness; 2) methods; 3) holding times and conditions; 4) negative controls; 5) positive controls; and 6) reference sediment performance.

Overall, no chemical data were rejected as unusable for this report, although some data were qualified. Conversely, Phase 1 bioassay data were rejected for regulatory purposes based on Ecology review (Michelsen, 1995). Major issues identified in the QA1 reviews are presented below. Data qualified by the laboratory are indicated in subsequent tables with a laboratory qualifier; refer to the complete laboratory QA1 reports in **Appendix C** for a discussion of qualifiers used. Modifications to laboratory qualifiers included: 1) laboratory qualifiers reported as <MDL were converted to a *U* qualifier; and 2) laboratory qualifiers reported as <RDL were converted to a *J* qualifier.

4.3.1 QA Review of Phase 1 Data

Particle Size Distribution

- An optional hydrogen peroxide digestion treatment (as referenced in PSEP) was used on four samples to minimize matrix interferences in the PSD analyses.
- Poor precision was observed throughout the phi size range without a consistent pattern. All PSD data were qualified as estimated (E).

Acid Volatile Sulfides

- In many cases, the sample triplicates were analyzed from two different sample containers collected for the same sample. Concentrations showed poor replicate precision. All AVS data were qualified as estimated (E).

Organics

- Extracts used to determine chlorobenzenes and related compounds by ion trap GC/MS were analyzed after the SAP specified hold time and are qualified as estimated (E). Matrix spike recoveries for these compounds were generally below 50 percent, and all chlorobenzene data are qualified with a G flag.
- Di-N-butyl phthalate, benzyl butyl phthalate, bis(2-ethylhexyl)phthalate, 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene were detected in at least one method blank. Associated samples were qualified with a B flag using National Functional Guidelines evaluation (i.e., for common lab contaminants, positive results are reported for concentrations more that 10 times the method blank level). The significance of method blank contamination for data interpretation purposes was evaluated by KCWPCD (**Appendix D**). The compound 1-4 dichlorobenzene was detected in some method blanks at levels below the RDL, and does not affect any sediment values that exceeded SQS/CSL criteria and are much higher than the RDL.

For bis(2-ethylhexyl)phthalate, sediment concentrations that exceeded SQS/CSL criteria also exceeded the method blank concentration by a factor greater than 10, so it is likely that bis(2-ethylhexyl)phthalate exists at these stations above the SMS criteria.

- Numerous pesticide/PCB and BNA matrix spike (MS) recoveries were outside QC acceptance criteria. Associated compounds were qualified with a G flag (MS recovery <50%), an L flag (MS recovery>150%), or an X flag (MS recovery <10%).

Bioassays

- Ecology independently reviewed the reported results for the three sediment bioassays and determined that the data sets were unusable for regulatory purposes (Michelsen, 1995). Data for two of three tests were considered invalid, and only the amphipod bioassay data appeared unaffected.
- Three QC issues were identified that affected the useability of results: 1) results of the positive control tests for the echinoderm larval bioassay showed that the larvae survived well above the normal control range and did not show a dose-response pattern when exposed to the control toxicant; 2) the initial starting weight of all of the polychaete *Neanthes* worms was lower than recommended by PSEP protocols, and relative growth was below SMS performance standards for 3 out of 4 reference stations; and 3) numerous water quality exceedances were noted for dissolved oxygen, pH, and salinity during the above testing.
- Since two test results were considered invalid, the bioassay data are unusable for comparison to SMS biological criteria and are not considered further in this report.

4.3.2 QA Review of Phase 2 Data

Organics

- BNA extracts were also analyzed by selected ion monitoring (SIM) to attain lower detection limits for chlorinated benzene compounds.
- N-nitrosodiphenylamine and di-N-butylphthalate were detected in method blanks for the BNA analysis. Associated sample results for these compounds have been qualified with a B flag.
- Surrogate recoveries were outside QC limits for numerous samples for the BNA analysis. Associated sample results for these compounds have been qualified with a G flag for surrogate recovery <50%.
- Standard reference material (SRM) recovery were outside QC limits for DDE and several PAH compounds. All 4,4-DDE sample results were qualified with an L flag based on SRM recoveries greater that 120%. Several PAH compounds were qualified with a G flag based on SRM recoveries of 43 to 79%.
- Matrix spike (MS) recoveries were outside QC limits for several chlorinated pesticide, BNA, and chlorobenzene compounds. For pesticide data, aldrin and 4,4-DDE were

qualified with an L flag for MS recoveries >150%; endosulfan I was qualified with a G flag for MS recovery<50%; and Delta-BHC and Endosulfan sulfate were qualified with an X flag for MS recoveries <10%. Several BNA compounds and chlorobenzenes were qualified with a G flag for MS recoveries <50%.

4.3.3 QA Review of Phase 3 Data

Particle Size Distribution

- Laboratory triplicate samples were analyzed for PSD. Because of the inherent heterogeneity of marine sediment samples, laboratory triplicate results often exceed the 20% RSD QC limit. The average RSDs over all grain size fractions were 20% and 9%. Laboratory triplicate results were reviewed to determine if a consistent difference in results occurred over all grain size fractions. Variations in triplicate results appear to be random and a function of inherent variations in samples rather than QC problems. As a result, PSD data have not been qualified based on laboratory triplicate results.

4.3.4 QA Review of Boeing Phase 3 Split Data

Due to the presence of Boeing stormwater outfalls in the study area, the Boeing Company decided to collect split samples with KCWPCD during the Phase 3 sampling effort. The Boeing splits were analyzed by Analytical Resources Inc. (ARI) of Seattle, Washington, for the following parameters: PCBs (EPA Method 8080); BNAs (EPA Method 8270); TOC (Method Plumb 1981); and total solids (Method EPA 160.3/SM 2540B).

Since KCWPCD did not analyze for BNAs during Phase 3, the Boeing split results for this parameter have been incorporated into the KCWPCD Norfolk database. It should be recognized that a QA1 evaluation has not been performed on the Boeing split data. A comparison between ARI and KCWPCD analytical results for PCBs and TOC is provided in **Appendix F**. These results indicate that the KCWPCD PCB values are generally greater than ARI PCB values (RPD = 8.3 to 154 percent), while TOC results are similar (RPD generally less than 24 percent).

4.4 SURFACE SEDIMENT RESULTS

Table 4-3 includes surface sediment (i.e., 0 to 10 cm depth) chemistry results for conventionals and SMS chemicals. Since the 1991 Consent Decree directed the EBDRP Panel to use Washington state sediment standards to determine the level of sediment cleanup, concentrations for SMS chemicals are compared to SMS criteria defined in WAC 173-204. SMS sediment quality criteria have been developed for the following effects levels:

- ***Sediment Quality Standards (SQS) criteria:*** Establishes a sediment quality that will result in no adverse effects on biological resources (WAC 173-204-320).

- ***Cleanup Screening Levels (CSL) criteria:*** Establishes minor adverse effects levels, above which station clusters of potential concern are defined as cleanup sites (WAC 173-204-530), and also establishes minimum cleanup levels (MCULs) to be used in evaluation of cleanup alternatives (WAC 173-204-560).

The SMS criteria for most nonionizable organic chemicals are listed in units of mg/kg organic carbon (OC). In order to compare to these criteria, laboratory chemical data expressed as mg/kg dry weight (DW) were converted to mg/kg OC, using the following equation:

$$\text{mg / kg OC} = \frac{\text{mg / kg DW}}{\text{TOC}}$$

where: TOC = percent total organic carbon expressed as a decimal fraction.

This conversion was calculated for each station, based on station-specific TOC data. For original DW concentrations of organic chemicals, refer to **Appendix B**.

Ecology has indicated that for low TOC sediments, comparison of nonionizable organic concentrations to OC-normalized SMS criteria may not be appropriate since the low TOC would not control chemical bioavailability. For these conditions, Ecology may allow a comparison of dry weight concentrations to dry weight Apparent Effects Threshold (AET) values on a site-specific basis to evaluate sediment toxicity (Michelsen, 1992). AET values have been developed for 64 organic and inorganic chemicals based on the observed relationships between biological effects and chemical concentrations (PSEP, 1988). Therefore, in addition to the SMS criteria comparison presented in **Table 4-3**, an additional comparison to AET values of four biological indicators is presented in **Table 4-4** for stations with TOC concentrations <0.2 percent. Comparison to lowest AET (LAET) values were used as an SQS surrogate, while comparison to the second-lowest AET (2LAET) values were used as a CSL surrogate.

For this report, the chemical summing method for chemical groups (i.e., total LPAHs, total HPAHs, total benzofluoranthenes, and total PCBs) followed SMS procedures, which includes: 1) using the highest detection limit reported for an individual chemical in a group when all chemicals are undetected; and 2) summing only the detected values when one or more chemicals in a group are detected.